Miscellaneous Paper HL-94-5
July 1994

(1)

US Army Corps
of Engineers
Waterways Experiment
Station

Development and Evaluation of a Sea Turtle-Deflecting Hopper Dredge Draghead

by *Glynn E. Banks, Michael P. Alexander*

Approved For Public Release; Distribution Is Unlimited

Prepared for Headquarters, U.S. Army Corps of Engineers

Miscellaneous Paper HL-94-5
July 1994

Development and Evaluation of a Sea Turtle-Deflecting Hopper Dredge Draghead

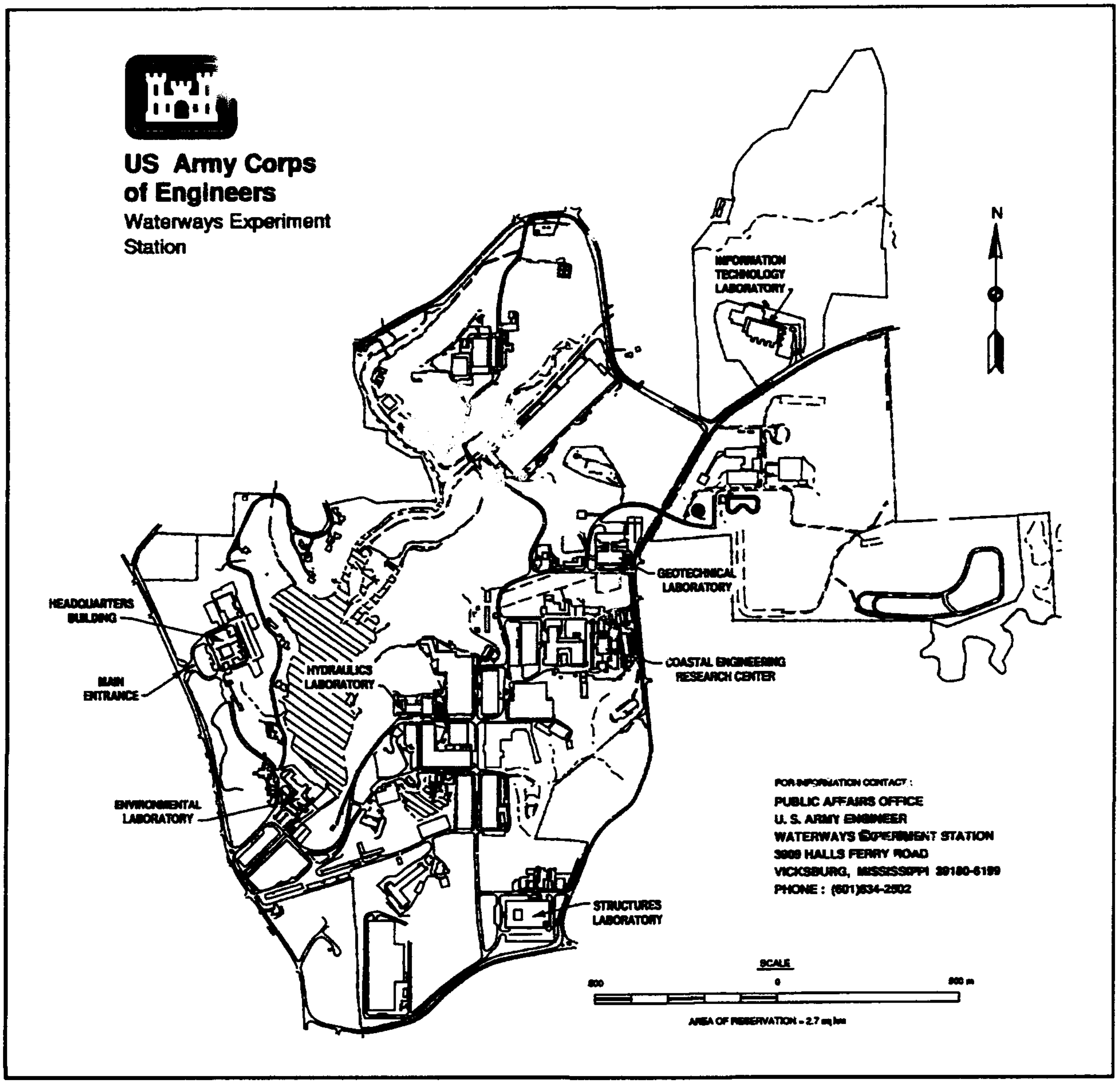
by Glynn E. Banks, Michael P. Alexander

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000



Waterways Experiment Station Cataloging-in-Publication Data

Banks, Glynn E.
Development and evaluation of a sea turtle-deflecting hopper dredge draghead / by Glynn E. Banks, Michael P. Alexander ; prepared for U.S. Army Corps of Engineers.
31 p. : ill. ; 28 cm. -- (Miscellaneous paper ; HL-94-5)
1. Dredges -- Environmental aspects -- Testing. 2. Sea turtles -- Protection. 3. Wildlife habitat improvement -- Evaluation. I. Alexander, Michael P. II. United States. Army. Corps of Engineers. III. U.S. Army Engineer Waterways Experiment Station. IV. Hydraulics Laboratory (U.S.) V. Title. VI. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; HL-94-5.
TA7 W34m no.HL-94-5

Contents

List of Figures

Preface

The sea turtle deflector draghead design, construction, and prototype evaluation resulting in this report was sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE). The subject deflector draghead prototype evaluation was a major effort under the HQUSACE Sea Turtle Research Program administered through the U.S. Army Engineer Waterways Experiment Station (WES). Field tests were completed 2-6 June 1993. Work resulting in this report was completed at the WES Hydraulics Laboratory (HL).

This report was written by Messrs. Glynn E. Banks and Michael P. Alexander of the Estuarine Engineering Branch (EEB), Estuaries Division (ED), HL, under the supervision of Mr. Frank A. Herrmann, Director, HL; Mr. Richard A. Sager, Assistant Director, HL; Mr. William H. McAnally, Chief, ED; and Mr. William D. Martin, Chief, EEB. Mr. E. Clark McNair, Coastal Engineering Research Center, WES, is the Sea Turtle Research Program Manager.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. nautical)	1.852	kilometers
pounds (mass)	0.4535924	kilograms
tons (long, mass) per cubic yard	1,328.939	kilograms per cubic meter

1 Introduction

Sea Turtle Problem

Dredging operations at coastal inlets maintain channel depths for commercial and recreational vessel traffic. A large portion of dredging in coastal areas is accomplished using hopper dredges, Figure 1, which remove bottom sediments through articulated suction pipes, discharging into a hopper within the vessel. Dredged material is usually hauled to a disposal site and released. Channel bottom contact and initial sediment entrainment is accomplished at the hopper dredge draghead. (Engineer Manual (EM) 1110-2-5025 gives a detailed description of the hopper dredging process.)[1] The slow-moving and nearly silent dragheads that make contact with bottom sediments during hopper dredging operation pose a potential threat to endangered sea turtles in certain areas, especially along the southeastern United States coastline.[2] Concern over the welfare of the endangered sea turtle species resulted in a U.S. Army Corps of Engineers research effort centered at the U.S. Army Engineer Waterways Experiment Station (WES). The Sea Turtle Research Program (STRP) was organized to limit or prevent sea turtle mortalities associated with hopper dredging.

Research focused on turtle population and behavior studies, methods to warn or scare turtles away from a dredging site, and modifications to hopper dredge dragheads so that they deflect rather than entrain sea turtles. This report describes work by the WES Hydraulics Laboratory to field test a full-scale prototype deflector draghead using the U.S. Army Corps of Engineers hopper dredge *McFarland*. A summary of design and model testing is also included.

---

[1] Headquarters, U.S. Army Corps of Engineers. (1983). "Dredging and dredged material disposal," Engineer Manual 1110-2-5025, U.S. Government Printing Office, Washington, DC.

[2] Dickerson, D. D., Nelson, D. A., Dickerson, C. E., Jr., and Reine, K. J. (1993). "Dredging related sea turtle studies along the southeastern U.S.," *Coastlines of the Gulf of Mexico*, American Society of Civil Engineers, New York.

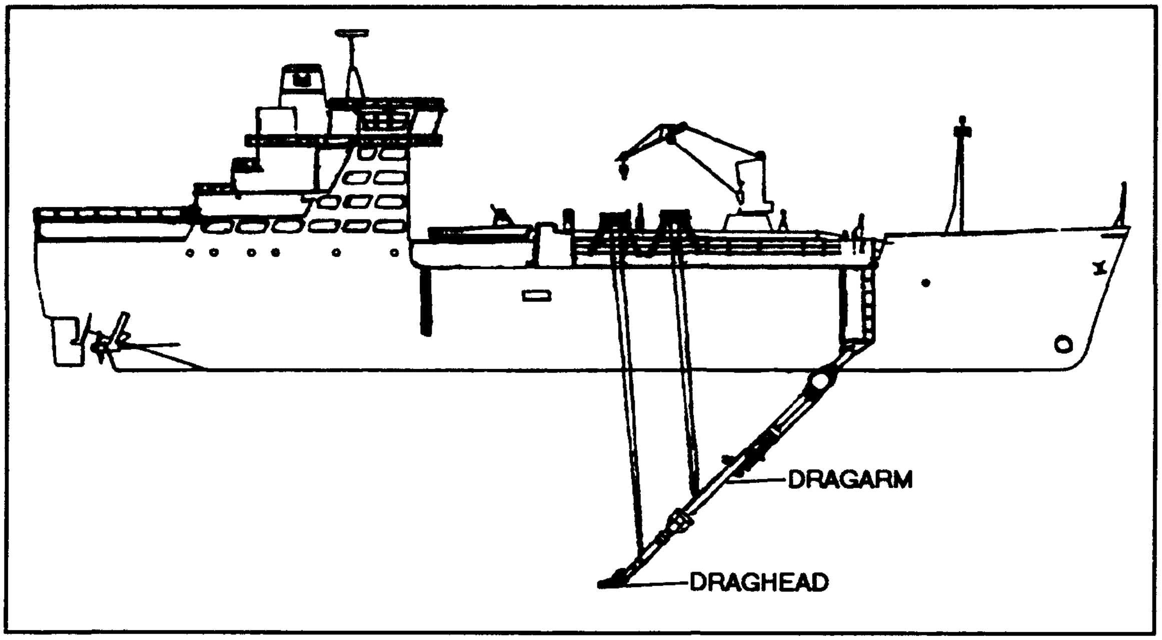


Figure 1. Schematic of a large hopper dredge, the U.S. Army Corps of Engineers "Wheeler"

Objective

The objective of this report is to summarize the design and model evaluations and to describe in detail the prototype performance of a new turtle-deflecting hopper dredge draghead. Prototype performance of the new draghead was based on its ability to deflect model turtles constructed specifically for the field trials, and on its production rate. Comparative data were collected with a conventional hopper dredge draghead both with and without the currently used chain deflector.

2 Background

Prior Accomplishments

Prior to establishing the STRP, hopper dredge draghead design and evaluation work had been completed under the U.S. Army Corps of Engineers Dredging Research Program (DRP). This work focused on improving material entrainment capability and overall efficiency. One of the design shapes conceived under the DRP work provided a starting point for a turtle-deflecting draghead design under the STRP. The design (Figure 2) featured a V-shaped leading edge that suggested that the draghead might be developed into a turtle-deflecting prototype. Achieving comparable production with conventional dragheads was essential; and since the DRP design was designed for improved production, it was promising in terms of maintaining production comparable to conventional equipment while deflecting sea turtles.

Also prior to the STRP, the U.S. Army Engineer District, Jacksonville, FL, sponsored the development and application of chain deflectors on conventional dragheads.[1] The chain deflector (Figure 3) is installed on the lead edge of conventional hopper dredge dragheads for use as a turtle deflector. Chain deflectors are currently used on Corps and contract dredges at designated East Coast sites. Although the chain deflector provides protection, maintaining it in proper working order is a problem. The forces encountered during dredging often bend the rigid members, break links, and break welded connections to the draghead. Damage to chain deflectors can go unnoticed for long periods during dredging since inspection can only be made when the dragheads are raised above the water surface. Experience with the chain deflector indicated that a stronger, more rigid, and permanent type of deflector would eliminate maintenance problems. A rigid deflector designed to withstand the forces encountered during dredging would significantly improve deflecting effectiveness because the deflector would remain intact for entire dredging cycles. Downtime associated with chain deflector repair during dredging operations could also be

[1] Dickerson, D. D., Nelson, D. A., and Banks, G. B. (1990). "Alternative dredging equipment and operational methods to minimize sea turtle mortalities," *Environmental Effects of Dredging Technical Notes*, EEDP-09-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

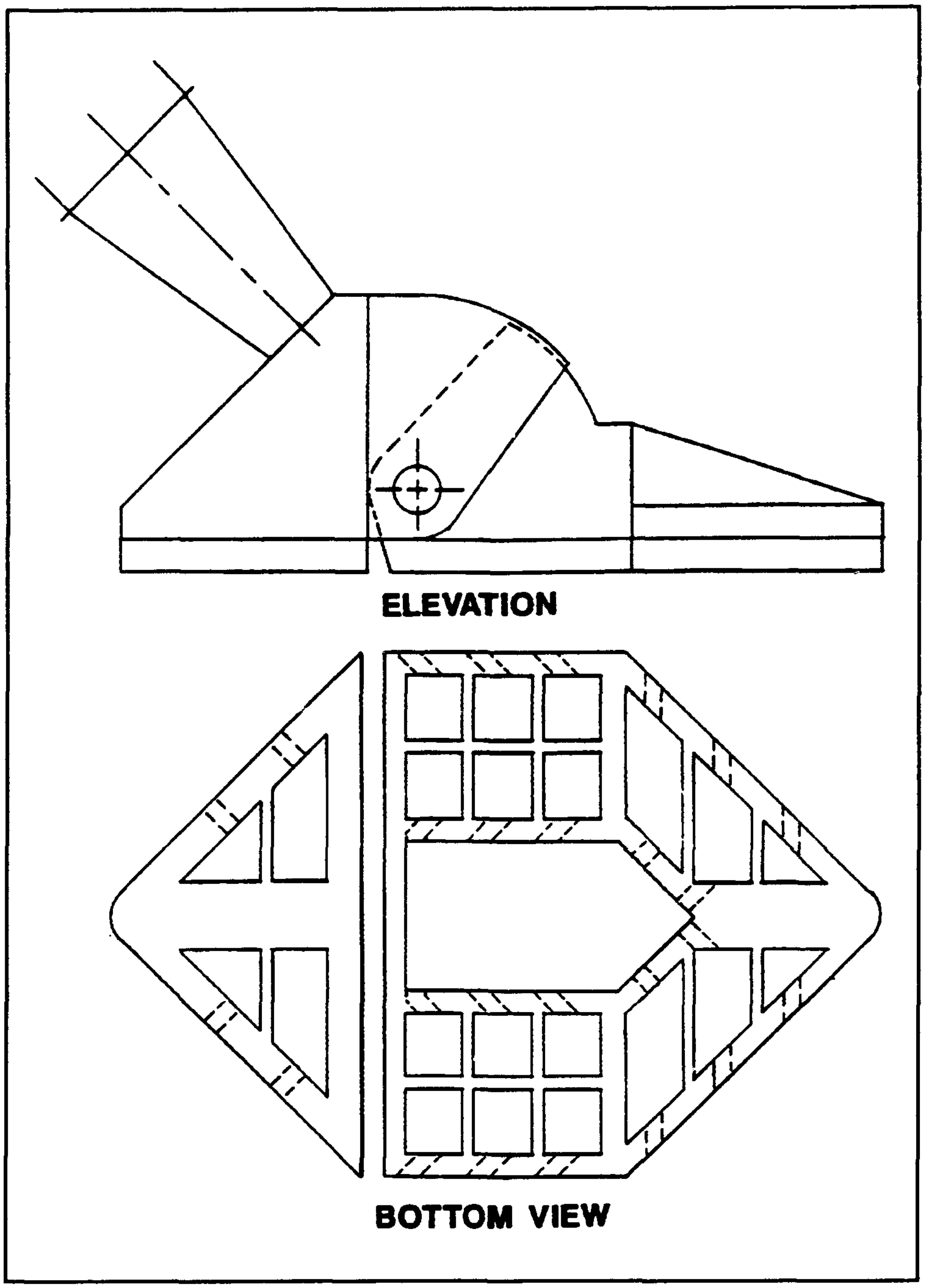


Figure 2. DRP draghead design

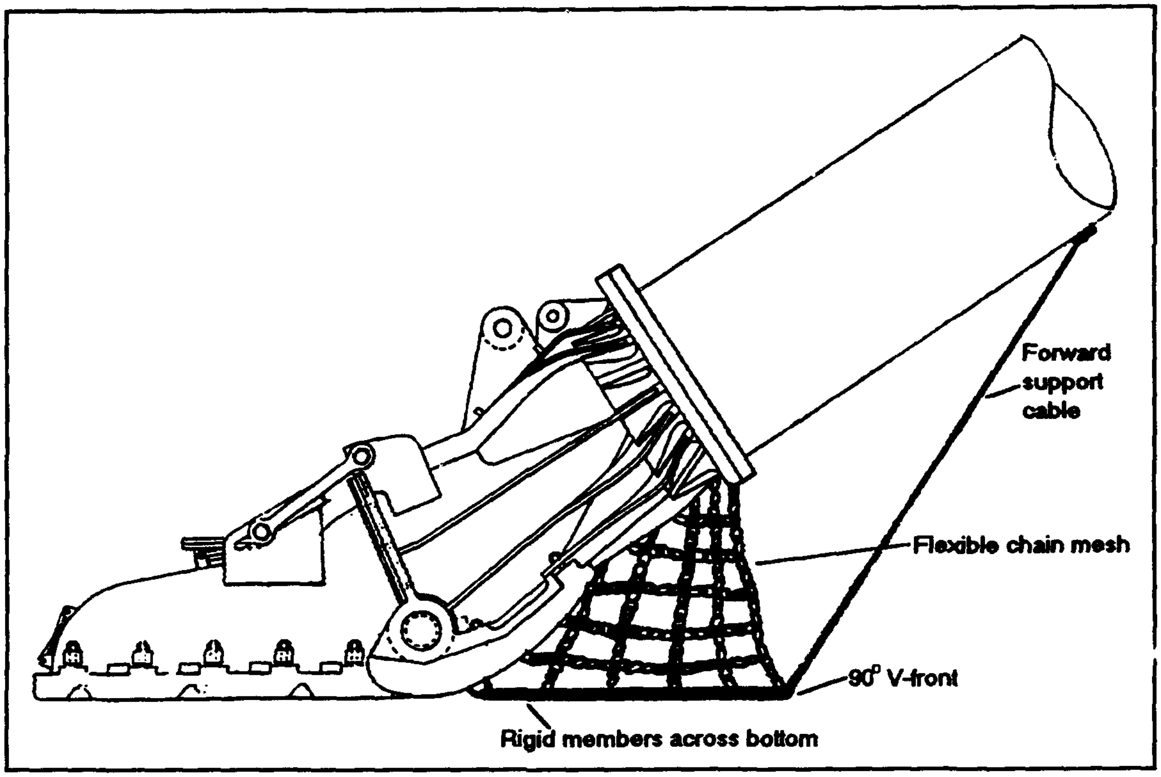


Figure 3. Chain deflector on standard California draghead

eliminated. Model tests of the chain deflector had been performed at the Hydraulics Laboratory Draghead Test Facility, and the STRP sponsored continued testing at the facility for the rigid deflector.

Hydraulics Laboratory Draghead Test Facility

The Hydraulics Laboratory Draghead Test Facility (Figure 4) consists of a concrete-walled flume with a mobile overhead carriage that supports a model dragarm. A scaled dredge pump and motor are situated on the carriage. An electric winch moves the carriage horizontally along the length of the facility for test runs.

The model rigid deflector tests were conducted with a leveled sand bottom in the test facility. The model rigid deflector draghead (Figure 5) was constructed to 1/6 prototype scale.[1] Neutrally buoyant foam discs were used in the test facility as model turtles. They were sized to correspond to an average sea turtle dimension at the 1/6 model scale. The model rigid

[1] Jorgeson, J. D., and Zawilla, J. S. (1993). "Protecting sea turtles during hopper dredging operations." *Proceedings of the twenty-sixth annual dredging seminar and WEDA XIV annual meeting*. Texas A&M University, College Station, TX.

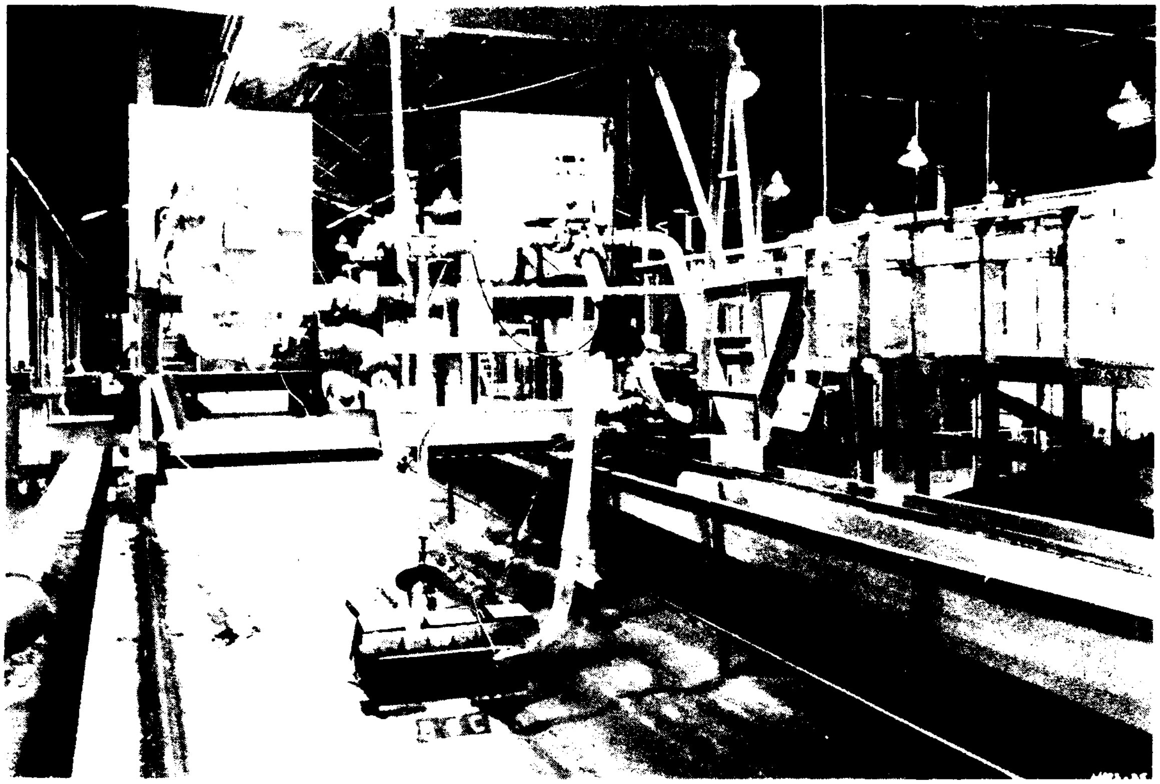


Figure 4. Hydraulics Laboratory Draghead Test Facility

deflector tests showed the design effective at both deflecting the model turtles and maintaining adequate production. Production values were comparable to standard California draghead model tests under identical conditions. The model rigid deflector tests were 100-percent effective at deflecting the model turtles in the test facility under the following conditions:

a. The model draghead stays hard on the bottom. The rigid deflector must make constant contact with the bottom to deflect turtles. Material may still be dredged because of pump suction if the draghead is close to bottom, but the draghead will simply move over the top of a model turtle and entrain it.

b. Proper lead edge angle is maintained. The lead edge angle is the angle of the heel pad relative to the channel bottom. The V-shaped heel pad edge (Figure 5) of the deflector needs to push a shallow riffle of sand ahead of the draghead. Constant bottom contact is ensured, and a sand "buffer" is formed between the draghead steel and turtle, allowing a gentle push away from the draghead path.

The Draghead Test Facility results were successful in evaluating a rigid deflector design. However, it was recognized that standard dredging practices generally focus on production alone. Maintaining a lead angle

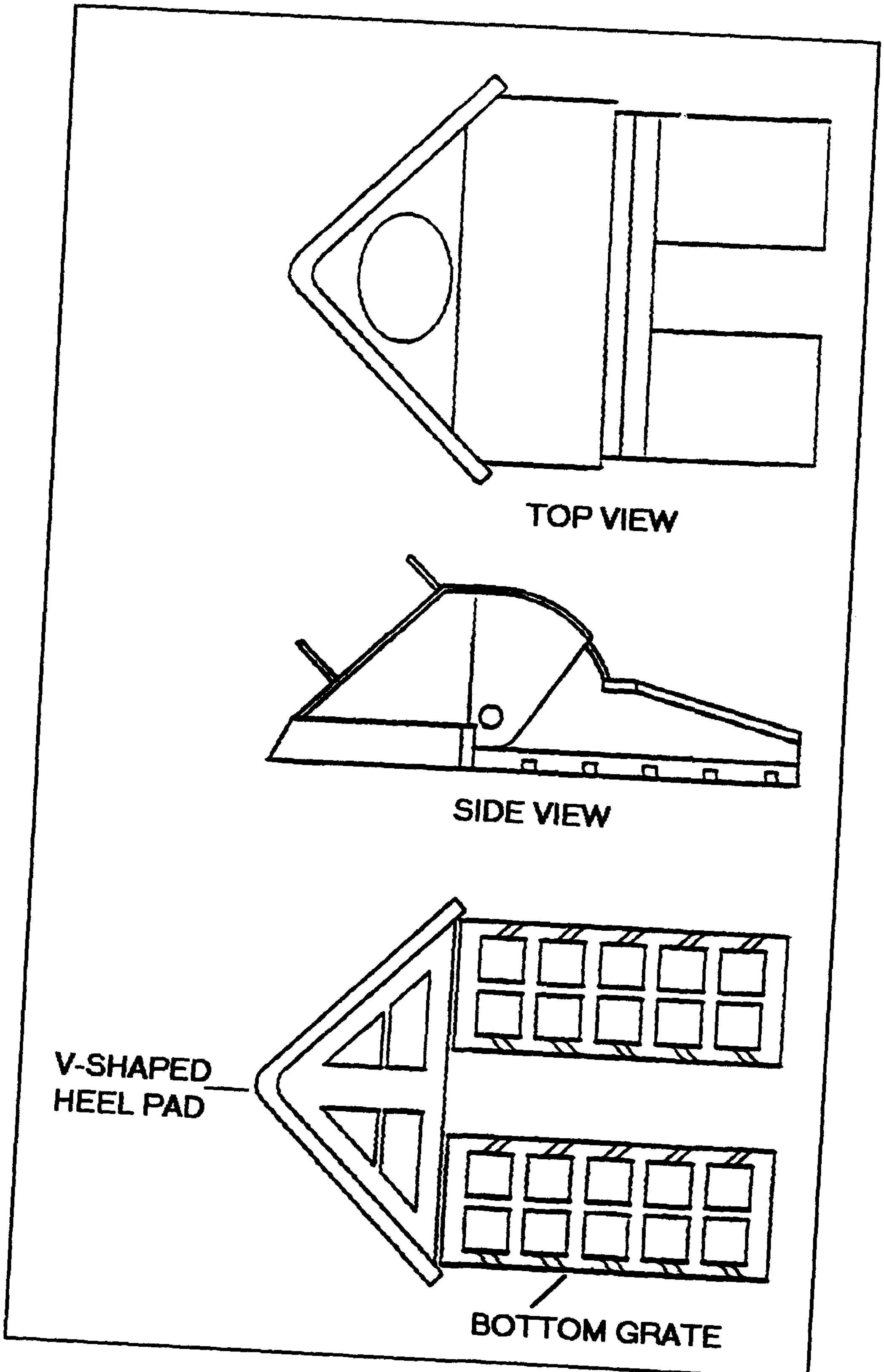


Figure 5. Scale model of deflecting draghead

position on a hopper dredge draghead while also maintaining hard bottom contact would constitute new operating concepts for the hopper dredging industry. It was further recognized that a full-scale prototype evaluation was necessary. A prototype field test of the rigid deflector was planned as a major effort of the STRP. The remainder of this report describes the field test of the prototype rigid deflector draghead.

3 Field Test Preparations

Prototype Rigid Deflector Draghead Construction

A cooperative effort between the U.S. Army Corps of Engineers Marine Design Center, Philadelphia District, Jacksonville District, and WES resulted in contract specifications for the prototype draghead construction. The prototype was built by NORSHIPCO in Norfolk, VA. Like the model rigid deflector, the prototype was a modified California draghead with a radically redesigned V-shaped heel pad. Figure 6 shows the prototype rigid deflector draghead.

The rigid deflector prototype was constructed for the Corps of Engineers hopper dredge *McFarland*. The *McFarland* is operated by the Philadelphia District and works along the Eastern United States coastline. Design specifications for the prototype draghead were based on an operating depth of 48 to 52 ft[1] and available on-deck ship clearances. The *McFarland's* draghead saddle design and available area on deck for the new V-front draghead did not significantly impact the model-to-prototype design goals. (This may, however, be a concern for other hopper dredges.) The design operating depth was selected for prototype testing. Other operating depths would require modifying the V-shaped heel pad angle.

Model Sea Turtle Construction

Prototype-scale model turtle construction presented a unique engineering task for the prototype draghead tests. The model turtles used in the draghead test facility for the model draghead were of comparatively simple construction and reuseable. Regulations prevented the use of plastics and related products that would not be compatible or degrade quickly at an ocean test site. Determining what type of material could be

[1] A table of factors for converting non-SI units of measurement to SI units is presented on page vi.

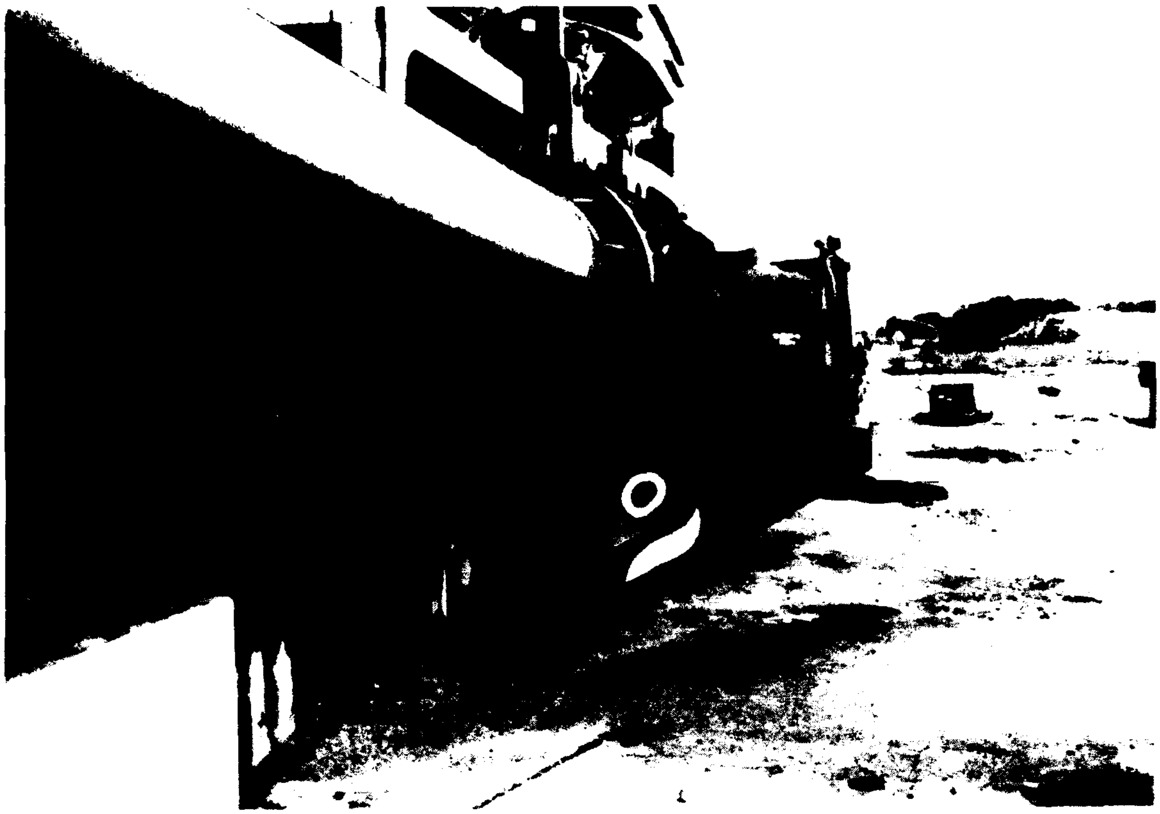


Figure 6. Prototype rigid deflector draghead installed on *McFarland*'s port dragarm

constructed to a size, shape, and weight similar to a live turtle specimen and how it could be mass produced at a reasonable cost for a large-scale field effort was a formidable task.

Sea turtles are not perfectly circular in planform, but a circular model turtle was considered sufficient for testing purposes. Representative turtle diameters were found to be around 22 in., and model turtle appendages were not considered necessary. The center portion of the model turtle body was planned to be around 6 in. thick, tapering to a 2- to 3-in. thickness around the perimeter so that a natural-looking shell model would result. Figure 7 shows a schematic of the model turtle form constructed at WES. A center hole was included to facilitate handling and placement.

WES Geotechnical Laboratory personnel provided an air-entrained concrete mix design that would match the submerged weight of a live turtle having the average dimensions discussed above. The model turtles were cast at WES using the air-entrained, low-strength concrete mix. A model turtle made of concrete (cement, sand, water, and air) was an acceptable material that could remain in an offshore dredged material disposal site following testing. Figure 8 shows a single model turtle, and Figure 9 shows the loaded models on their way to the field test site.

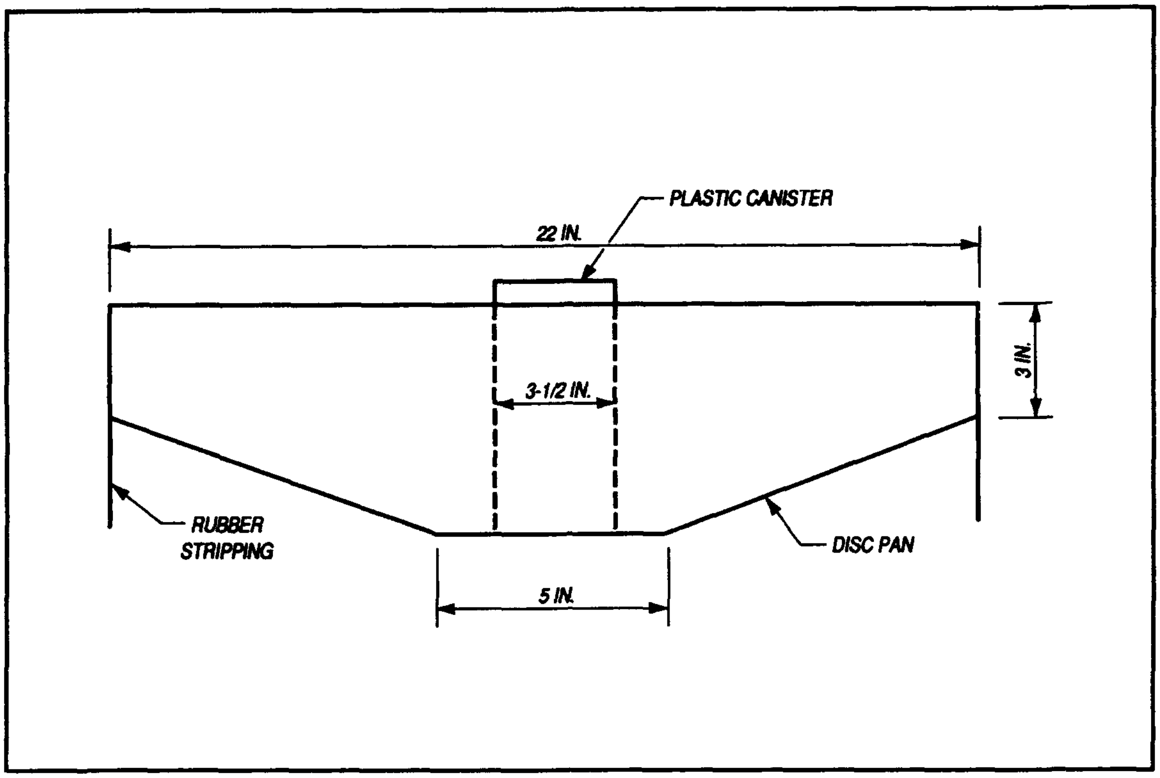


Figure 7. WES model turtle form

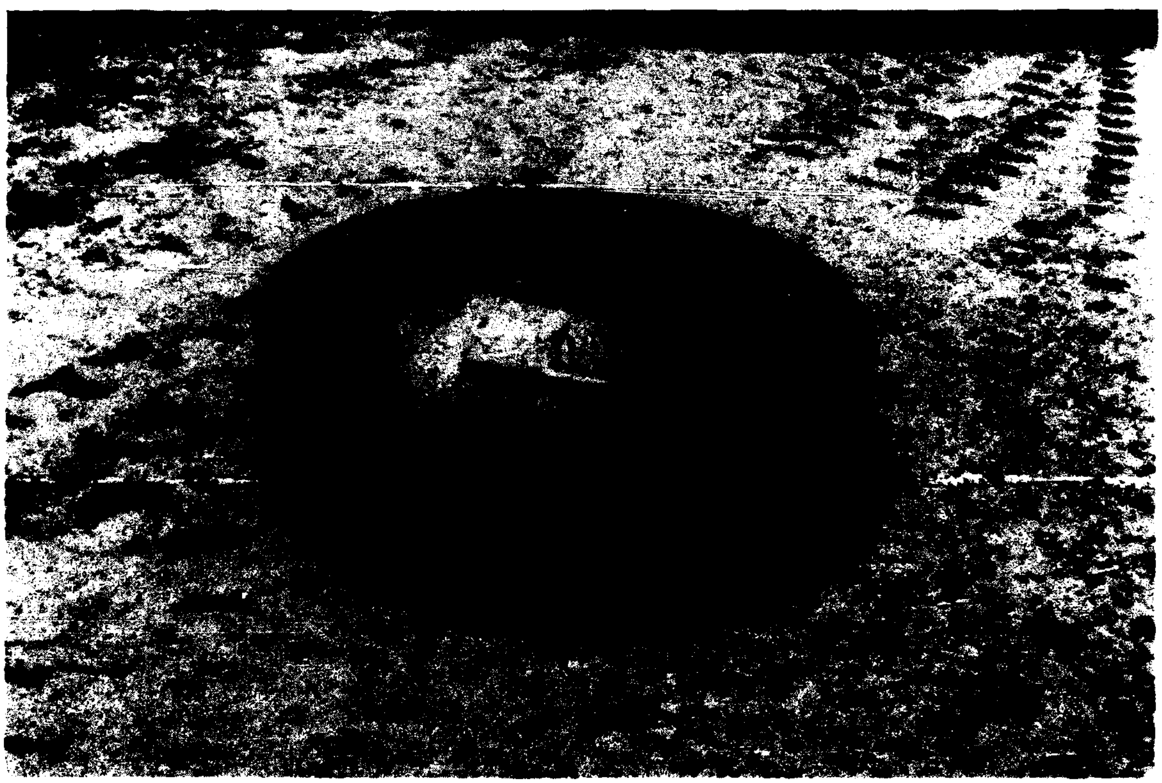


Figure 8. Single model sea turtle

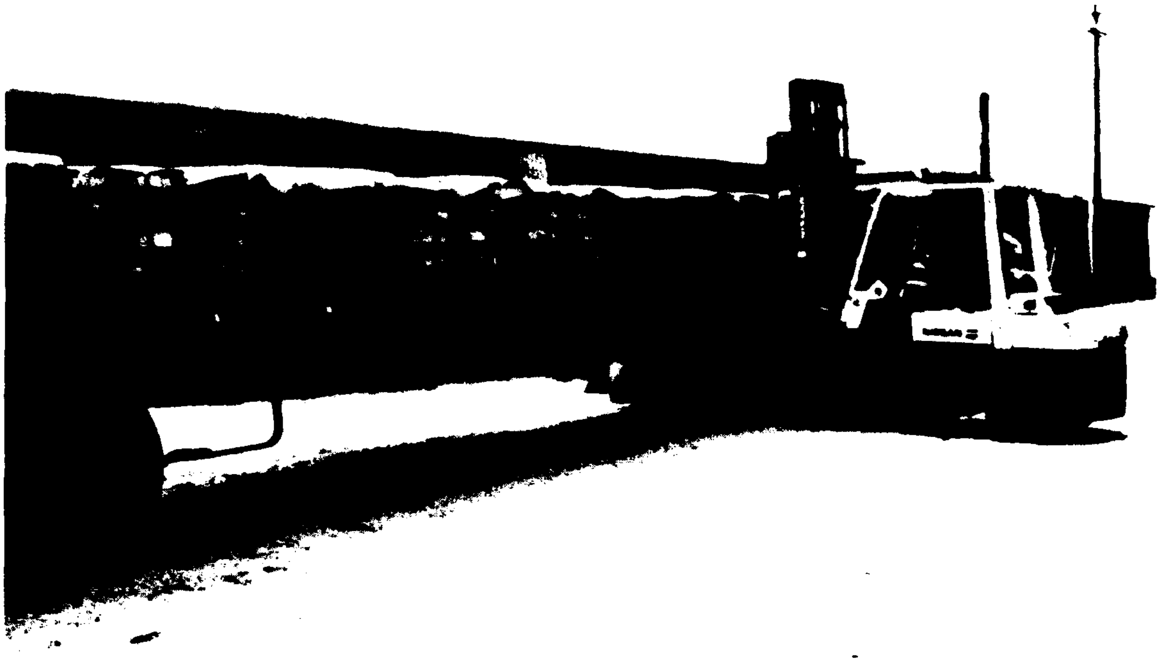


Figure 9. Truck loaded with model turtles en route to field test site

Field Test Site

Several candidate field sites were considered as the hopper dredge *McFarland* was dispatched to the Jacksonville District for dredging assignments. Desirable site conditions included good water clarity for underwater observations, smooth bottom topography, low bottom current velocities (so that the model turtles would remain in position), and a location without protected mammal or fisheries resources. Since dredging operations at Fort Pierce, FL, were planned for July 1993, the Fort Pierce offshore disposal site was selected for field testing. The disposal site bottom was relatively flat, ranging from 48 to 52 ft deep. Water clarity was expected to be good, and little current was expected. The site was relatively free of marine life, and a small boat was arranged to continuously patrol the vicinity for right whale or sea turtle activity.

Two areas within the disposal site were delineated for testing, the sea trial site and the model turtle grid (Figure 10). The model turtle grid was arranged into five rows of 60 model turtles each. Rows were 240 ft long and spaced 250 ft apart to form a rectangular grid. The separate sea trial testing area was necessary to determine proper operating conditions prior to evaluating performance of the new draghead in the model turtle grid.

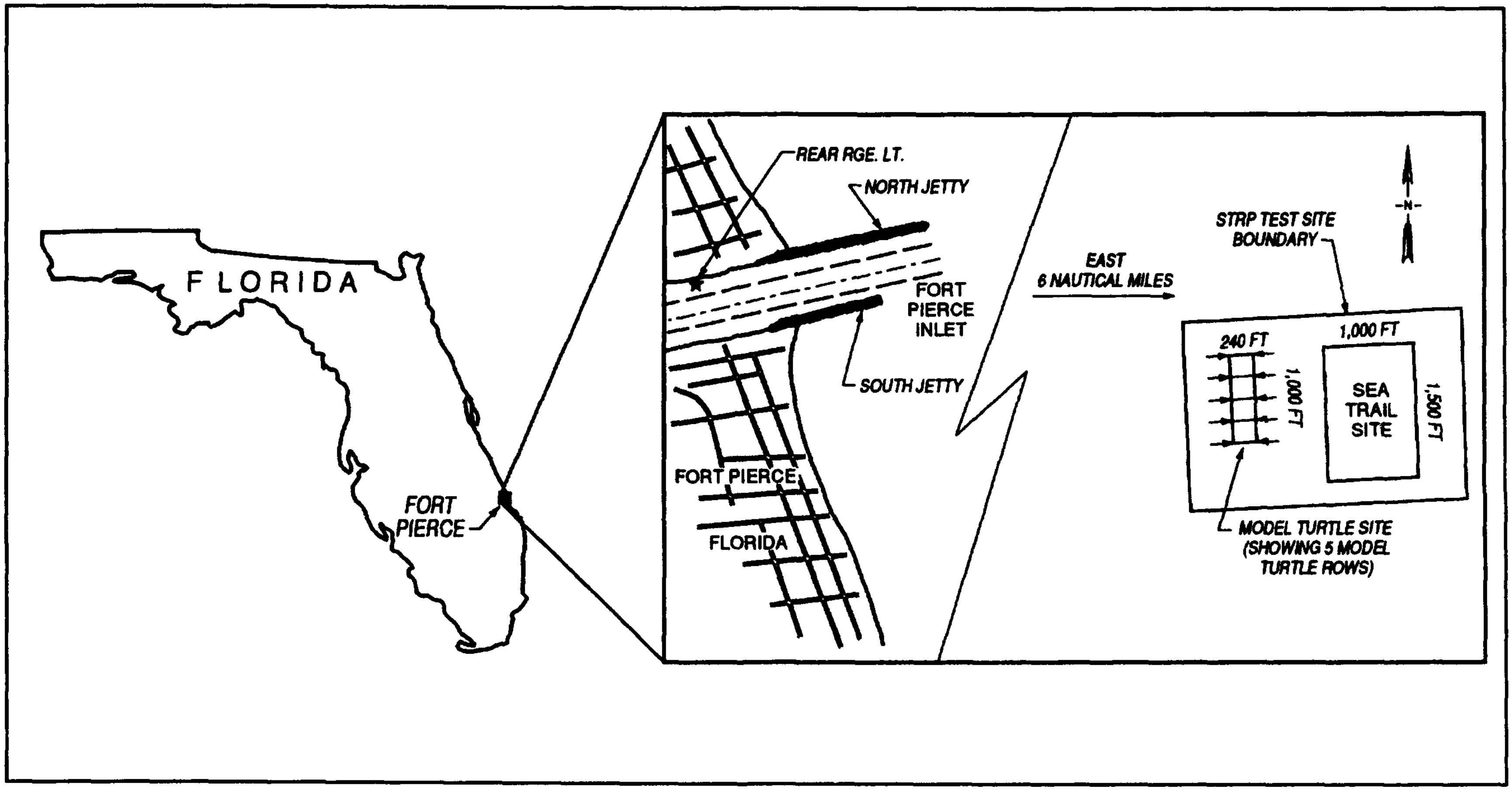


Figure 10. Test site locations

Required Instrumentation

Hopper dredge dragarms are an articulated combination of suction pipes leading from fixed piping on the vessel through trunnion and ball joints (Figure 11). These joint angles control the draghead position angle on the bottom, and small-angle variations are not critical to conventional draghead operation. Trunnion and ball joint angles are not normally monitored on hopper dredges. However, real-time draghead positioning is a requirement for using the rigid deflector draghead.

Prior to testing, an instrumentation package was developed and installed on the *McFarland*'s dragarms so that draghead position angles could be monitored and adjusted. The instrumentation consisted of pressure transducers and inclinometers mounted on the dragarm and draghead to provide depth and angle information. A pressure transducer was also secured outside of the dredge control room to monitor atmospheric pressure and integrate corrections to the system. Inclinometers were installed on the upper dragpipe near the trunnion and on the lower dragpipe near the

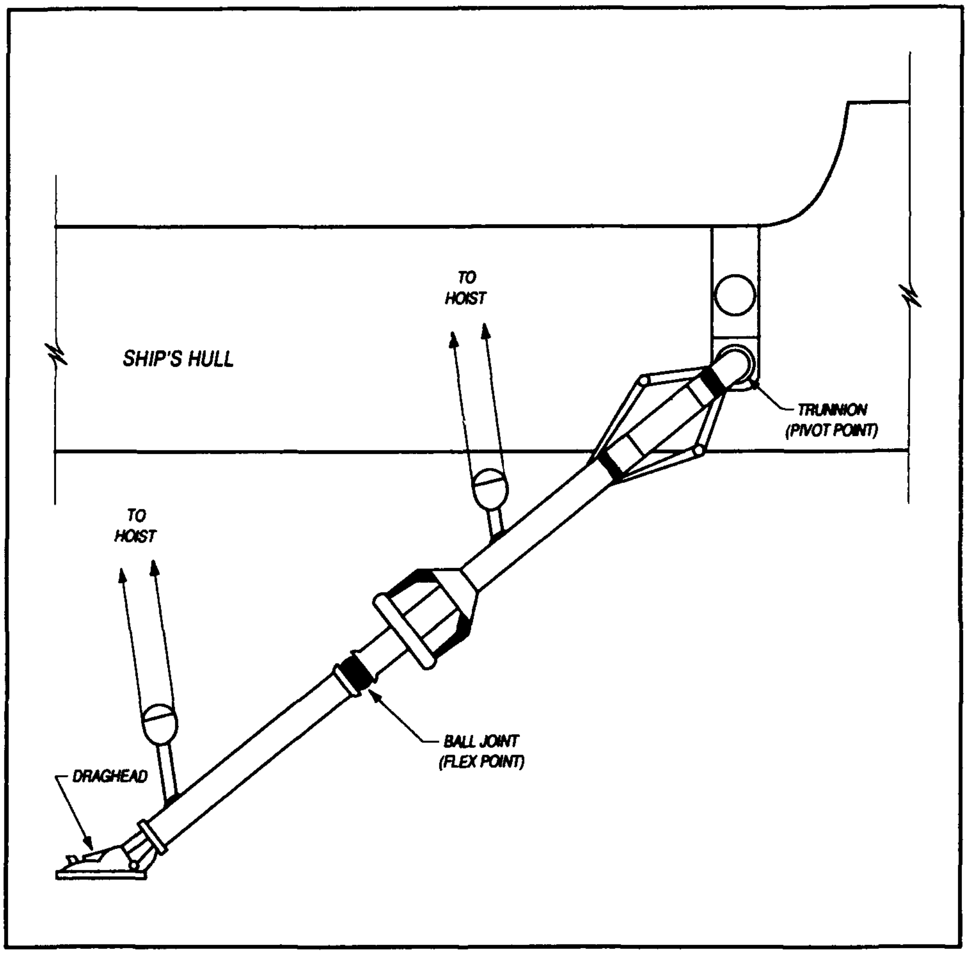


Figure 11. Sketch of hopper dredge dragarm showing relative positions of trunnion and ball joint

ball joint. All inputs were routed to a small computer in the control room. Real-time depth and differential-angle information were displayed and relayed to the dragtenders.

Field Test Goals

The rigid deflector draghead tests were designed to thoroughly evaluate the effectiveness of the rigid deflector draghead. Two general test goals were addressed:

a. Visual Observations of Effectiveness. Draghead positioning on the bottom required visual observations. Guidelines for using the new draghead were determined using underwater cameras. Visual observations were also used to determine the draghead effectiveness at deflecting model turtles.

b. Comparative Performance of Dragheads. This task included evaluating the model turtle-deflecting ability of the standard California draghead with and without the chain deflector. Testing the chain deflector allowed a prototype scale evaluation of existing technique deflecting capability. Prior to the STRP, only model evaluations had validated the chain deflector capability. A base condition was obtained using the standard California draghead without the chain deflector. The *McFarland* is outfitted with production meters, and comparative production data were also collected and considered a critical performance element to evaluate the rigid deflector.

4 Field Test Operations and Analyses

Model Turtle Deployment

Field test activity began with a contract to a local Fort Pierce, FL, area salvage company for diver placement of the model turtle grid. A Jacksonville District/WES team worked with the contractor providing Differential Global Positioning System grid layout. Each model turtle grid row end point was located with the Jacksonville District global positioning satellite unit and marked with anchored buoys. A hard-hat diver (contractor) secured a line on the bottom from one grid cross-section row end point to the other cross-section end point. The line was marked on 4-ft centers so that 60 model turtles could be positioned on each row. The model turtles were sent to the bottom diver from a work barge (Figure 12). A line was secured from the barge to the row end anchors. The line was passed through the center hole in each model from the barge as it was cast overboard. The submerged weight of the models was 4 to 5 lb, and they gently sank down the surface-to-bottom line to the bottom diver. The barge was positioned and anchored over each of the five cross-section rows to complete model turtle placement. The marked ropes used for bottom positioning were removed as each row of model placement was completed.

Equipment Installation on the *McFarland*

While model turtle deployment was in progress at the Fort Pierce test site, the dredge *McFarland* was docked at Jacksonville, FL. Just prior to the *McFarland*'s departure to the Fort Pierce site, a second Jacksonville District/WES team worked at Jacksonville to install the dragarm positioning system and underwater video camera mounts on the dragarms.

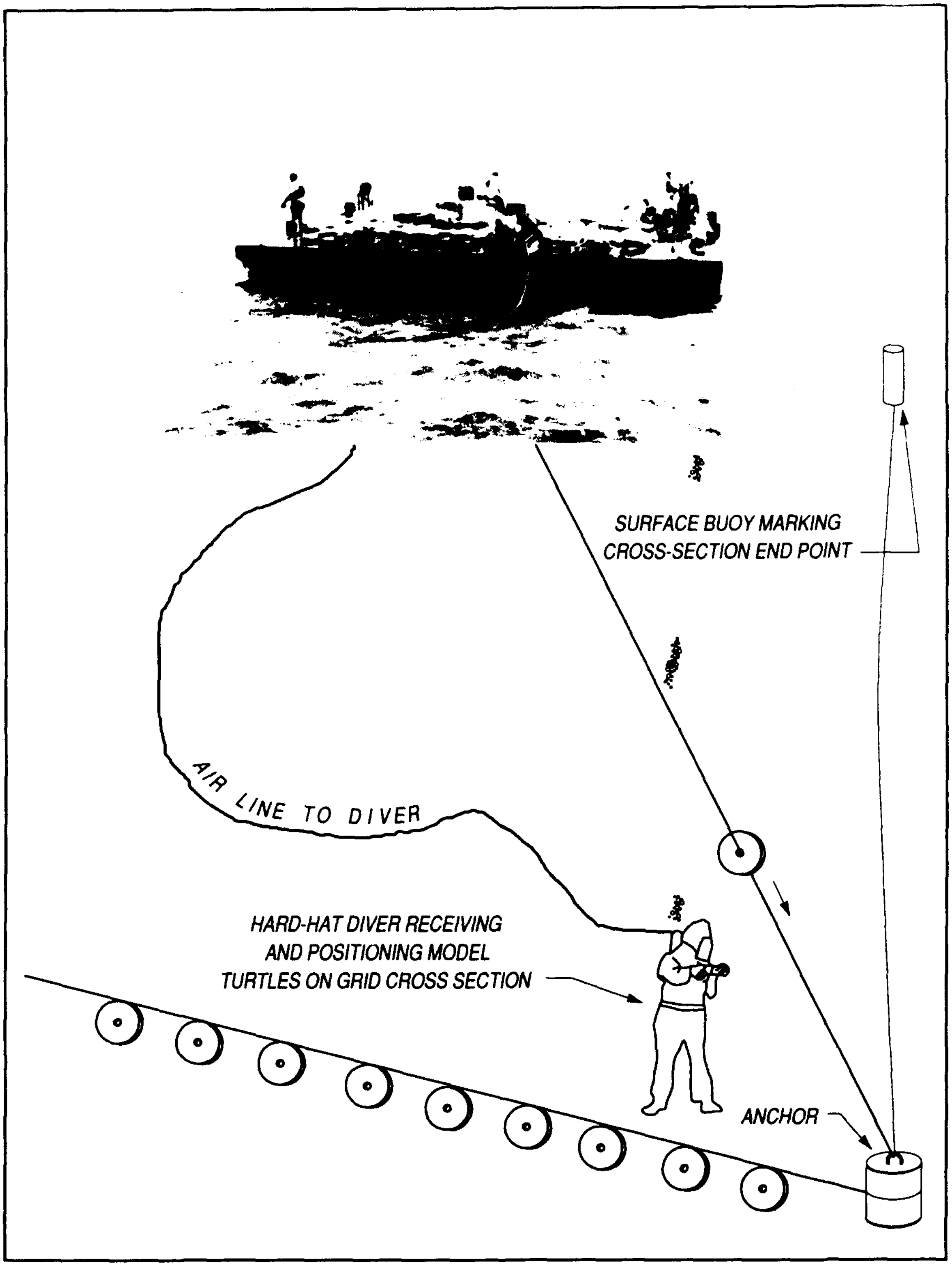


Figure 12. Model turtle deployment

Sea Trials

The *McFarland* arrived at the Fort Pierce test site on 2 June 1993. The model turtle grid was completed, and testing the prototype rigid deflector began. An underwater camera captured the full V-shaped deflector view on a video monitor in the control room. A second camera and control room monitor were set up to view the draghead side area. Video cassette recording equipment was used to store pertinent draghead operation footage.

Several dredge lines were run while observing the lead edge position of the rigid deflector draghead on the bottom. Irregular bottom topography and wave action can cause the draghead to skip or hop along the bottom during dredging. This condition was observed on the video monitors. Depending on the material being dredged, some hopper dredge dragheads are operated just above bottom to balance material and water intake to prevent plugging pipelines. Procedures developed for the rigid deflector draghead were to maximize bottom contact and allow the V-shaped lead edge of the deflector to push a riffle of sand. This condition, like that in the model draghead test facility, was expected to provide a deflecting sand buffer to gently push the model turtles out of the draghead path. The optimum rigid deflector operating conditions were as follows:

a. *Adjust the upper and lower dragpipes to a straight pipe condition.* A straight pipe condition was achieved with a zero angle reading for the dragpipe ball joint. The real-time display allowed the dragtender to quickly adjust to this condition.

b. *Operate the Draghead hard on bottom.* This allowed the lead edge of draghead to push the desired riffle of sand to buffer model turtle impact.

Video observations of the working prototype under these operating conditions were virtually the same as those observed for the model in the draghead test facility.

Field Performance Descriptors

To evaluate draghead performance in the model turtle grid, several terms were applied to describe models affected by the draghead. An "encounter" was regarded as a model turtle in the oncoming draghead path that was relocated in some way by the draghead. Encounters were further described as "deflected," "damaged," or "entrained." Deflected model turtles were pushed to the side of the oncoming draghead and buffered from any dangerous impact by the sand riffle ahead of the deflector. Damaged was defined to be noticeable chips, breaks, or scratches to the models. Entrained models were taken in with the dredged slurry and deposited in the

hopper. The entrained models were fragmented as they passed through the draghead grate and dredge pump, and therefore were comparable with a live specimen mortality.

Rigid Deflector Performance in the Model Turtle Grid

Multiple tracklines through the model turtle grid provided a total of 39 encounters with model turtles. Most of the encounters were successful deflections. (Table 1 provides a tabulation of the rigid deflector test results in the model turtle grid.) Two model turtles were entrained in the draghead suction when the draghead lost contact with the bottom as it moved over a depression. The two entrained models were in a noticeable depression; and on this particular test run, the crew was advised to follow their normal draghead positioning procedures and ignore (for comparative test purposes) the hard-on-bottom, straight-pipe condition. This case of model turtle entrainment points out that design operation procedures should be followed for maximum deflecting capability. Also, there may be times when a sea turtle may be located in a depression similar to where the two models were so that it would be entrained if the swell compensation system did not react fast enough to keep the draghead hard on bottom.

Table 1
Prototype Draghead Model Turtle Grid Results

	Draghead Type					
Parameter	**Rigid Deflector**		**Chain Deflector**		**Standard California**	
Encounters (total)	39		34		28	
Deflections	37	95	29	85	5	18
Damaged	0	0	1	3	9	32
Models entrained with dredged material	2	5	4	12	14	50
Production, yd^3/min	37		33		35	

Note: Where two numerals are given, first = total; second = percent of total.

In addition to deflecting capability, what effect, if any, that the V-shaped lead draghead edge would have on vessel steering and maintaining course along a dredged trackline was unknown prior to the prototype rigid deflector tests. The ship captain, however, reported somewhat easier steering with the V-shaped prototype than conventional dragheads. The V-shape apparently reduces drag forces encountered with conventional draghead shapes. It is significant that the new design did not adversely impact maneuverability.

Chain Deflector Performance

Prior to the STRP tests, no prototype chain deflector tests using underwater video had been done. Following the rigid deflector draghead tests, the video equipment and instrumentation package were switched to the starboard dragarm where a standard California draghead was outfitted with a chain deflector. The sea trial site was used for video observation of the chain deflector during normal dredging operations. It was noted that the lead edge of the deflector was not sliding on the bottom as it should. The forward support cable (Figure 3) had to be lengthened to allow the deflector to make contact with the bottom. Otherwise, the chain deflector would have been ineffective. Also notable was a much less prominent sand riffle pushed ahead of the chain deflector bottom bars (when proper adjustment was achieved), implying an increased possibility for damage to a turtle. Optimum operating procedures for the standard California draghead with chain deflectors was determined to be the same as for the rigid deflector: a straight-pipe, hard-on-bottom operation.

Dredged tracklines through the model turtle grid resulted in 34 model turtle encounters. Four model turtles slid under the deflector and were entrained with dredged material. One other model turtle was damaged. Of the four entrained turtles, one of these was initially pinned under the forward support cable on the front of the chain deflector before it slid under.

Standard California Draghead Performance

The final draghead field test evaluated a standard California draghead without any turtle deflecting modifications. This provided a statistical base condition with which the rigid deflector and chain deflector effectiveness could be compared. The chain deflector was removed from the starboard draghead, leaving the conventional California draghead without any sea turtle-deflecting mechanism.

To be statistically compatible with the rigid deflector prototype and chain deflector tests, the standard California tests were conducted with the same straight dragpipe and hard-on-bottom draghead operation. The standard California draghead encountered 28 model turtles during test runs. Fourteen of these were entrained with dredged material. Another 14 were deflected, but 9 of these were damaged as they were deflected.

Model Deflection and Production Comparison

Table 1 summarizes the number of model turtle encounters, deflections, and damages for the prototype draghead field tests. These results are believed to be conservative when considering a live turtle. A live turtle

would naturally swim away from immediate danger, and the turtle's effort could be expected to reduce, at least, the number of damages.

The rigid deflector successfully deflected 95 percent of the model turtles it encountered. The chain deflector was comparatively effective, deflecting 85 percent of the models that it encountered. The standard California draghead only successfully deflected 18 percent of the models that it encountered. Table 1 shows that a significant increase in draghead-deflecting capability can be realized using either the rigid deflector draghead or chain deflectors on conventional dragheads. Qualifying deflecting capability with the specified operating procedures and adjustments previously discussed is important.

Hopper dredging is expensive, and a deflector draghead that reduced standard production rates would be a costly drawback for possible future deflector draghead requirements on hopper dredges. The *McFarland*'s production metering system was used to calculate volumes of material for each dredged line through the model turtle grid. Table 1 shows averaged production values for the three draghead tests. The rigid deflector prototype production rates are comparable with the conventional California draghead production. (Appendix A provides additional production evaluation details.)

5 Conclusions and Recommendations

Conclusions

A new rigid sea turtle deflector hopper dredge draghead was constructed and field tested. The rigid deflector prototype proved most successful at deflecting model sea turtles by comparison with a standard California draghead with and without the currently used flexible chain deflector mechanism. Under specified operating conditions while dredging, the rigid deflector draghead was easiest to maintain position along dredge tracklines. The rigid deflector draghead also resulted in comparable (slightly higher) dredged material production rates than did the conventional draghead. However, effective turtle deflection requires following the operating and adjustment procedures described in this report. The prototype-scaled model turtle field test is believed to be a reliable indicator of how the new draghead will deflect real turtles.

Recommendations

When measures are required to reduce impacts to sea turtles during hopper dredging operations, the rigid deflector draghead described in this report can provide the best available deflection capability for a sea turtle situated in the oncoming draghead path. The existing prototype can be used within its design operating depths of 48 to 52 ft. Consistently monitoring and adjusting dragarm positioning to ensure proper deflecting orientation, adding the required instrumentation if necessary, is recommended.

Further developing the prototype so that it can be adjusted to work in a wider range of operating depths is also recommended. This will require developing bottom contact angle adjustment capability at the V-shaped heel pad. The current prototype bottom contact is controlled by the trunnion and ball joint angle positions on the dragarm. Heel pad angle adjustments may allow more flexibility with the trunnion and ball joint angle positions, resulting in more versatile operating criteria.

Appendix A
Production Evaluation Details

The production metering system on the *McFarland* includes nuclear density meters on the discharge pipes from the port and starboard dredge pumps that lead into the hopper. The field trials in the model turtle grid began with the rigid deflector prototype draghead that was installed on the port dragarm. The port production metering system worked properly, and the required production information was collected.

Table A1 provides details of the four rigid deflector tracklines through the model turtle grid along with the standard California draghead, with and without the chain deflector. Some problems were encountered with the starboard production meter system electronics. This required swapping some electronic components from the port side production meter. The starboard side of the system was then calibrated onsite just prior to the standard California draghead tests with and without the chain deflector. Questionable readouts from the system are noted in Table A1, but the recorded total volumes appeared accurate. Thus, production was acquired for the standard California draghead with and without the chain deflector.

Table A1
McFarland Production Tests - Fort Pierce, FL
(1,000-ft lines, straight dragpipe condition, hard on bottom, 48- to 50-ft depth)

Type of Draghead	Date	Line Number	Start Time End Time Elapsed Time	Average Speed fps	Average Density long ton/yd^3	Average Velocity fps	Total Volume yd^3	Volume Unit Time yd^3/sec	Remarks
Standard California No Deflector Starboard Pump	5 Jun	4	15:14:07 15:17:16 189 sec	5.29	0.992*	30.1*	87	0.4603	Average Standard California production - 0.5774 yd^3/sec
Standard California No Deflector Starboard Pump	5 Jun	3	15:43:35 15:47:02 207 sec	4.83	0.992*	30.1*	125	0.6039	Average Standard California production - 0.5774 yd^3/sec
Standard California No Deflector Starboard Pump	5 Jun	11	16:15:54 16:19:52 238 sec	4.20	0.961*	30.1*	159	0.6681	Average Standard California production - 0.5774 yd^3/sec
Standard California Chain Deflector Starboard Pump	5 Jun	9	11:22:36 11:25:11 155 sec	6.45	0.992*	30.1*	76	0.4903	Draghead went down late, but 1,000-ft distance was covered. Average Chain Deflector production - 0.5583 yd^3/sec
Standard California Chain Deflector Starboard Pump	5 Jun	13	12:39:58 12:44:05 247 sec	4.05	0.992*	30.1*	133	0.5385	Average Chain Deflector production - 0.5583 yd^3/sec
Standard California Chain Deflector Starboard Pump	5 Jun	4	13:13:49 13:17:21 212 sec	4.72	0.992*	30.1*	137	0.6462	Average Chain Deflector production - 0.5583 yd^3/sec
Modified California Rigid Deflector Port Pump	6 Jun	6	12:51:36 12:55:07 211 sec	4.74	0.918	21.55	124	0.5877	Average Rigid Deflector production - 0.6211 yd^3/sec
Modified California Rigid Deflector Port Pump	6 Jun	6	13:13:01 13:16:10 189 sec	5.29	0.909	20.04	97	0.5132	Bounced off bottom, poor ball joint angle (not in average production)
Modified California Rigid Deflector Port Pump	6 Jun	3	13:32:26 13:34:59 153 sec	6.54	0.884	22.36	70	0.4575	Poor ball joint angle too high by 4 to 5 deg (not in average production)
Modified California Rigid Deflector Port Pump	6 Jun	12	14:00:37 14:04:59 262 sec	3.82	0.918	24.56	175	0.6679	Average Rigid Deflector production - 0.6211 yd^3/sec
Modified California Rigid Deflector Port Pump	6 Jun	10	14:21:39 14:24:17 158 sec	6.33	0.922	21.92	96	0.6076	Average Rigid Deflector production - 0.6211 yd^3/sec

* Printed average density and average velocity values for the Starboard pump are in question since recorded total volumes appear to be accurate.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
July 1994

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Development and Evaluation of a Sea Turtle-Deflecting Hopper Dredge Draghead

5. FUNDING NUMBERS

6. AUTHOR(S)
Glynn E. Banks, Michael P. Alexander

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Miscellaneous Paper HL-94-5

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers, Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Protected sea turtle species frequent some navigation channels that must be maintained by the U.S. Army Corps of Engineers. Most of these channels are maintained by hopper dredging, and sea turtle injuries and mortalities may result as the flat sloping lead edge of conventional hopper dredge dragheads encounter a sea turtle. A new hopper dredge draghead was developed that could deflect, rather than damage or entrain, a sea turtle during dredging operations. A prototype of the new rigid deflector draghead was constructed and installed on the U.S. Army Corps of Engineers hopper dredge *McFarland.*

This report describes the development and field testing of the new rigid sea turtle deflector draghead. Flexible chain deflecting mechanisms for conventional dragheads are described, and the rigid deflector draghead was evaluated based on comparative test runs using a standard California draghead. Field-test preparations included the construction and placement of prototype model sea turtles. Results show successful sea turtle-deflecting capability and comparable production rates with the conventional California draghead. Hopper dredge operating procedures critical to successfully using the rigid deflector draghead are also included.

14. SUBJECT TERMS
Draghead
Hopper dredging
Sea turtles

15. NUMBER OF PAGES
31

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102